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REINFORCEMENT OF POLY (POLYMETHYLMETHACRYLATE) WITH CARBON FIBER AND ALUMINA AS A COMPOSITE MATERIAL FOR ORTHOPEDIC IMPLANT

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ABSTRACT

In this work ,experimental and theoretical properties of composite materials are presented. The optimal mechanical properties of the polymer polymethyl methacrylate (PMMA) material that used in manufacturing internal Orthopaedic .The (PMMA) is used as matrix reinforced by two materials ,composite with Carbon-fibre(CF) and alumina (Al2O3). The composite materials are controlling three variables; the existence, amount of (Al2O3 and CF) and the type of angle distribution CF. The tensile test used to study the mechanical properties. The scanning electron (SEM) linked with energy dispersive spectroscopy (EDS) and optical microscopy were per sained the presence of the materials, microstructure and solidified samples. The solid work program was used to make model for bone bridge drowning in three dimensions. The model was used by the finite element analysis ANSYS 14.5 program that is used to design sample orthopaedic (humerus bone section) and test load 10 Kg applied on it. The theoretical results agree with experimental results in terms of tensile test that is the composite material PMMA+AL2O3+CF) with uniform distribution for CF give better properties in terms of increasing in Yield stress, decreasing density and maximum deformation.

Key words: Mechanical Properties, polymethyl methacrylate PMMA, Carbon-fibre(CF),oxide alumina (Al2O3), ANSYS14.5.

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1. INTRODUCTION

The composite Carbon-fiber-and polymer implants progress several benefits over conventional metal implants . Polymethyl methacrylate PMMA are physiologically harmless because of their low moisture absorption capacity, not attacked by enzymes and moulds [1]. The important PMMA material for transplants and prosthetics due to it is compatible with human tissue, especially in the field of ophthalmology because of its transparent properties. Their fatigue strength is greater than most metal implants and lower modulus of elasticity better matches that of bone[2,3]. Carbon-fibre used for reinforcing polymethyl methacrylate (PMMA) implants (matrix) offer several benefits over traditional metal implants. In the past few years, Carbon-fibre was used as reinforced composite implants materials have gained more attention. This trend, highlighted by more clinical articles on the availability of implant options by using carbon-fibre-reinforced composite implants material, is supported by good scientific laboratory data on the biomaterial and biomechanical properties of these implants [1]. The strong bonding is created between carbon fibres and PMMA matrix during the formation phase of the composite material[4].Polymer material have biocompatibility properties that lead to interfere the screws made from polymer for ligament fixation implant[5]. The certain musculoskeletal tumours was treated by using carbon -fibre [6] . The composite of Carbon-fibre- reinforced PEEK polymer was used in orthopaedic surgery [7]. The composite material from polymer PMMA, hydroxyapatite (HA) and carbon nanotube have good biocompatibility and mechanical properties used in bone bridges or internal orthopaedic surgery [8] . The addition of Al2O3 in different types of phase alumina powder to the PMMA as composite materials created direct bone formation on their surfaces in vivo test and also caused the enhancement in mechanical properties such as the strength and Young's modulus [9].The present Al2O3in composite material increased the hardness of material also the optical microscopy image shows it have uniform distribution in matrix composite[10].Finite element analysis(FEA) include of computer geometry of a design that is stressed and analyzed for specific results. In other words, FEA is a numerical method to find out an approximate solution for variables in a problem which are difficult to obtain analytically [11]. In this paper ,a comparison has been made between composite material with different concentration and present materials to investigate the mechanical properties such as Young's modulus by using tensile test .The finite element analysis by ANSYS 14.5 program was used to design sample orthopaedic (humerus bone section) and test the load applied on it [12] .

2. MATERIALS & EXPERIMENTAL PROCEDURES

2.1. Materials

The polymethyl methacrylate PMMA acrylic poly with nano size (methyl 2-methylpropenoate) with chemical formula(C5H8O2)n provided from (Czech Republic jerman)used as matrix .Carbon fibers (CF) are fibers about5-10micrometre in diameter and consist of mostly carbon atoms . Alumina alpha phase (Al2O3),with purity 99.0%and particle size 40 nm provided from SkySpring Nanomaterial's. Carbon fibers (CF) and Alumina were used as reinforcement.

2.2. Methods

2.2.1. Practical Work

The composite materials control three variables; the existence , amount of (AL2O3 and CF),and the angle distribution of CF .The typical procedure , polymer PMMA used as matrix reinforced by CF with different concentration (uniform distribution with angle 45° and non-uniform distribution angles)and Al2O3 with 1% concentration[10].The first mixtures contain 99% PMMA with 1%Al2O3,second mixtures contain 94%PMMA with 1% Al2O3 and 5% CF 1N(non uniform distribution) ,third mixtures contain 89% PMMA with 1% Al2O3 and 10% CF 2N(non uniform distribution) , fourth mixture contain 98% PMMA with 2% CF 1U(uniform distribution) , fifth mixture contain 97% PMMA with 1% Al2O3 and 2% CF 1U(uniform distribution) .All samples the mixtures were pressed in tensile stainless-steel mould with standard dimension (length140mm,width 13mm and thickness 3 mm) [13],the pressing was done , under 10 MPa pressure for 20 min duration by using hydraulic press at room temperature . Mechanical pressing used to produce samples with same dimension of mould. Tensile test was performed according to the national standards as ASTMD638Band D790-2005, using JIN DAO AG-1 testing machine at room temperature to improve the reproducibility[14] as shown in Fig.1. The cross-head speeds are 0.1 mm/min with pressure 25 N . The density of each sample calculated by using Archimedes principle as shown in table 1 , $\rho = \frac{M}{V}$ ....(1) where ρ density of solid material ,M mass and V volume [15] . Five samples are suggested from fifteen samples depend on the results of tensile test(Stress peak) due to their increasing in peak stress and density . The dispersive spectrometer (SEM,EDS, PHILIPS XL series, japan). With electron probe, an acceleration voltage 15 KV was used to study the concentration elements in PMMA+AL2O3+CF 2U sample with results shown in table 2 .The optical microscopy was used to study microstructure of the surface .

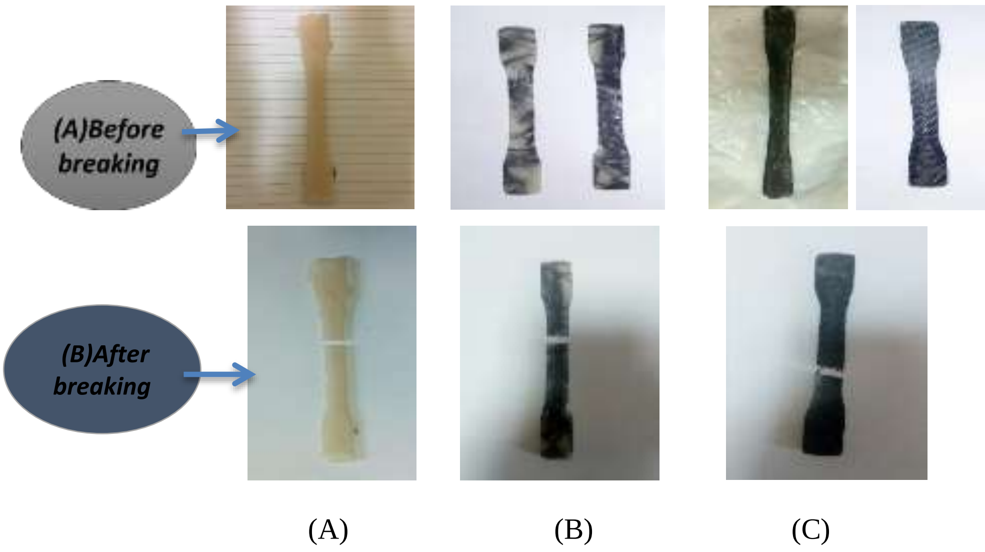


Figure.1. SAMPLES DUE TO APPLIED TENSILE TEST A-(PMMA+AL2O3), B- (PMMA+AL2O3+CF N) ,B- (PMMA+CF U) ,D-(PMMA+AL2O3+CF U).

2.2.3. Theortical

Graphing of the Geometry and boundary condition

Bone bridge which drawn by using (solid work) were processed according to default pattern in three dimensions(length15cm,width 2.5cm and thickness 3mm) .The dimension was taken from the same bone bridge that was done in measurement of experimental part as shown in Fig. 2. The purpose of drawing models by solid work is to be used in ANSYS workbench program for modeling, meshing and defining boundary condition such as applied load. The model become ready to analysis by ANSYS program at first meshing. The mesh of the model divided the geometry into elements and nods as shown in Fig. 3 .The second step was applying the boundary conditions on model such as locating the position of fixed support and applied load ,the bridge bone fixed at upper part and applied tension force at lower part. The general contour of Von Misses stress and deformation for the bone bridge resulting from the ANSYS (14.5) program. From this section, the value of force that applied on the bridge bone at homeruns bone section was obtained .This value of force was measured by Suspending a weight of (10) kg at infected arm of the patient so as to apply a boundary condition in FEM solution and calculate the value of generated stressed and deformation in the bridge bone.

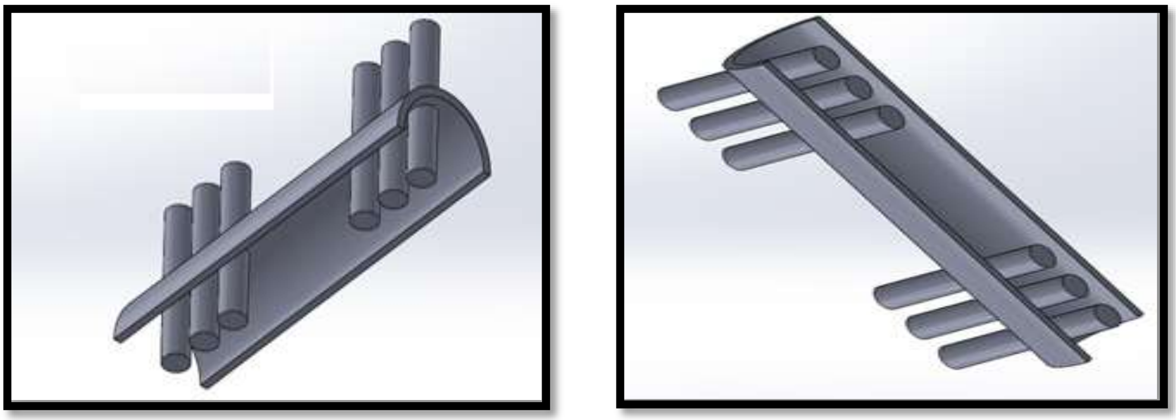


Figure. 2. Bone Bridge Drawn By Using (Solid Work) Which Were Processed According To An Default Pattern In Three Dimensions (LENGTH 15cm,WIDTH 2.5cm and THICKNESS 3mm).

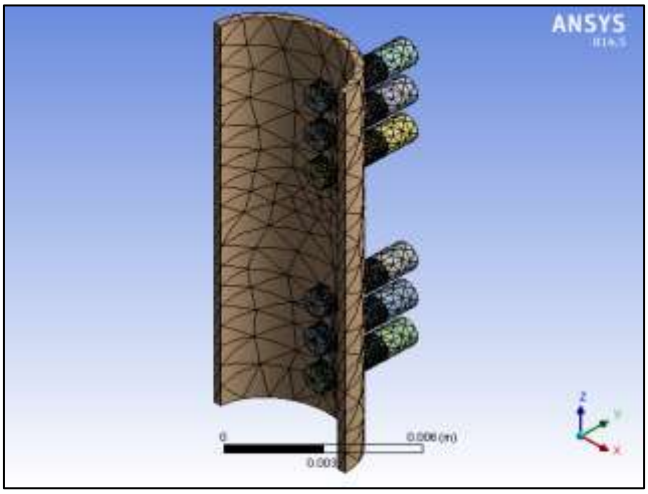
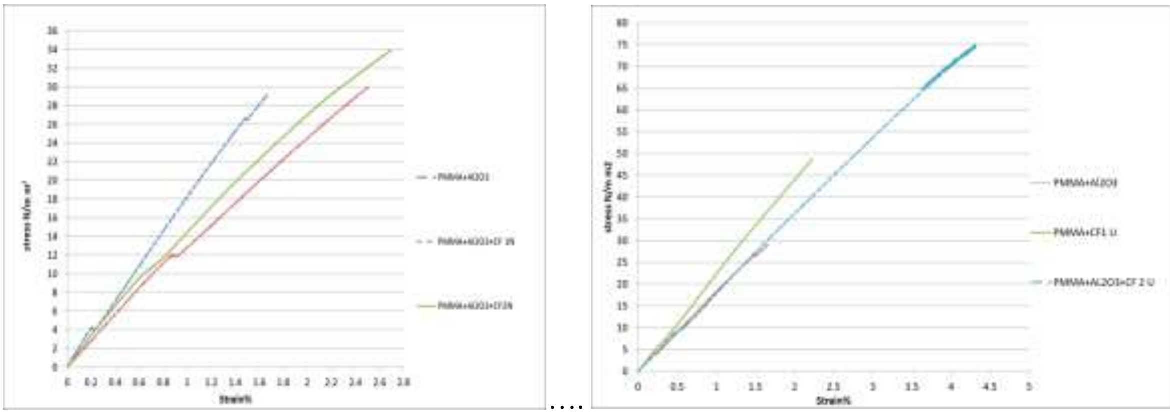


Figure. 3. Use In Ansys Workbench,Program For Modeling, Meshing and Defining Boundary Condition As Applied Load 10 Kg.

3. RESULT AND DISCUSSION

3.1. Mechanical Properties

In general the peak stress and density variations due to different percent composite of oxide alumina and carbon–fibre. The CF and AL2O3 were used to improve and overcome weakness in the mechanical properties of polymer PMMA which leads to increasing in the Yield stress and decreasing in the density of composite samples[16]. The heat result during formation of the polymer lead to energizing the AL2O3 to fusion with PMMA especially the AL2O3 have strong hardness .Also the CF made strong bridge to the PMMA which is very important for orthopedic toughness. From Fig.(4.a) and table(1), there are increasing in Yield stress(30 ,33.982)Mpa and decreasing in density(1.6& 2) g/cm3 for sample 2&3(94%PMMA+ 1%AL2O3 +5%CF 1N & 89%PMMA+ 1%AL2O3 +10%CF 2N) respectively compared with sample1(99%PMMA+1% AL2O3) have Yield stress (28)Mpa and density (2) g/cm3 this belong to present CF .The mechanical properties improved at increasing the percentage of CF in composite, with non-uniform distribution. From Fig.(4.b) and table(1),showed a high improvement in mechanical properties for Al2O3 composite sample (97%PMMA+1% AL2O3 +2%CF 2U) compared with(98% PMMA+ 2% CF 1U) which have yield stress(48.836 &75.28)Mpa and decreasing in density(1.5& 1.3) g/cm3 respectively at using CF with uniform distribution angle 45°. As a comparison, the mechanical properties enhancement for using CF with uniform distribution angle 45° with respect no uniform distribution although increasing the percentage of CF composite .



(A) (B)

Figure.4. Shows Tensile Testing for Samples:(A) (PMMA+AL2O3) (PMMA+AL2O3+CF1N),& (PMMA+AL2O3+CF 2N), (B) (PMMA+AL2O3) , (PMMA+ CF U))&(PMMA+AL2O3+CF U).

Table 1 The Concentration Percentage, The Mechanigal Proertise and Density of Sample

Material	Polymer (PMMA) %	Alumina (AL_2O_3) %	Carbon Fiber (CF)%	Min stress pa	Max stress Mpa	Yield stress Mpa	Min deformation (mm)	Max deformation (mm)	Density g/cm^3
PMMA+ AL2O3	99	1	…..	2.55	41.5	28	0	0.18	2.41
PMMA+ AL2O3+CF 1N	94	1	5	2.57	43.4	30	0	0.25	1.6
PMMA+ AL2O3+CF 2N	89	1	10	2.57	42.8	33.982	0	0.27	2
PMMA+ CF 1U	98	…..	2	2.58	43.2	48.836	0	0.15	1.5
PMMA+ AL2O3+CF 2U	97	1	2	2.58	43	75.28	0	0.18	1.3

3.2. Microstructural Investigation

Microstructural surface investigations by using optical microscopy solidified of sample PMMA+AL2O3+CF 2U(uniform distribution 45°) with different magnifications. Fig.5 shows Al2O3 particles is uniform distributed in polymer PMMA matrix and the line of CF is very clear in the form of network structure work as a bridge to increasing of bonding between PMMA matrix and Al2O3 .The grain boundary is clear belong to composite materials with different phase. No crack on surface sample due to better interface and solidified during preparation process .

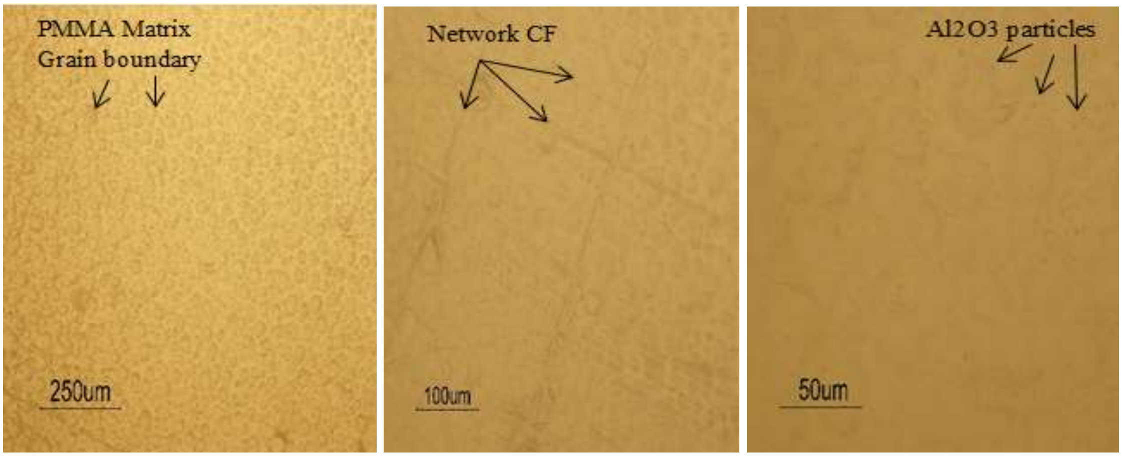


Figure.5 Optical Microscopy PMMA+AL2O3+CF 2U(With Uniform Distribution 45°)

Also the microstructural of surface investigations by using said view image of SEM linked with an EDS attachment showed that the PMMA matrix reinforced by AL2O3 and CF with uniform distribution which is very clear in Fig .6 with magnification 5um.

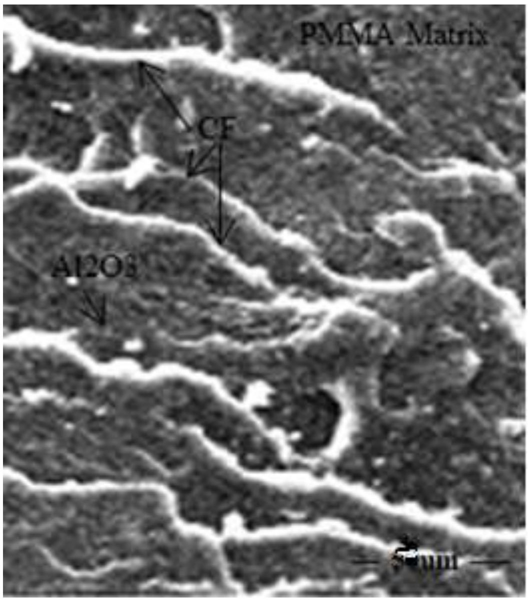


Figure.6. SEM Images of the PMMA+AL2O3+CF 2U(with Uniform Distribution 45°)

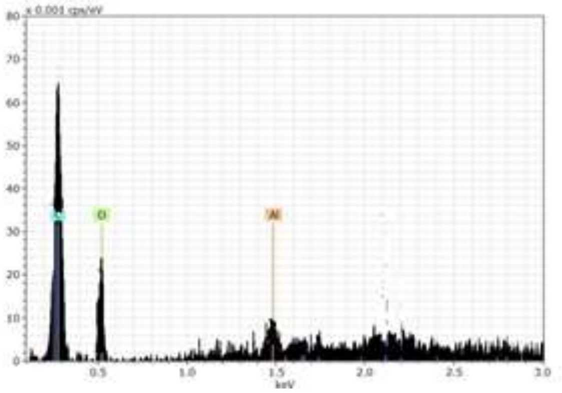


Figure. 7 EDS Spectra Of PMMA+AL2O3+CF 2U(With Uniform Distribution 45°)

Table 2 Elements Concentration

Element	*Wt%*	*At%*
O K	25.55	48.76
AlK	07.67	08.68
CK	66.78	42.56

The chemical composition of PMMA+AL2O3+CF 2U was investigated by using energy dispersive spectroscopy (EDS) . Fig.7. shows the energy transitions elements Al Kα and C Kα are 1.48 KeV and 0.277 KeV respectively and energy transitions elements O Kα are 0.5 KeV. The concentrations of the elements listed in table 4.2 related to PMMA+AL2O3+CF 2U(with uniform distribution 45°).The increasing in concentration of C atom belong to present it in CF and PMMA compost.

3.3. Boundary Condition

To analysis stress generation and distortion in bone section ,it must be apply the boundary condition which include one end of the bone should be fixed and loud 100N applied on other hand , as show in Fig.8.

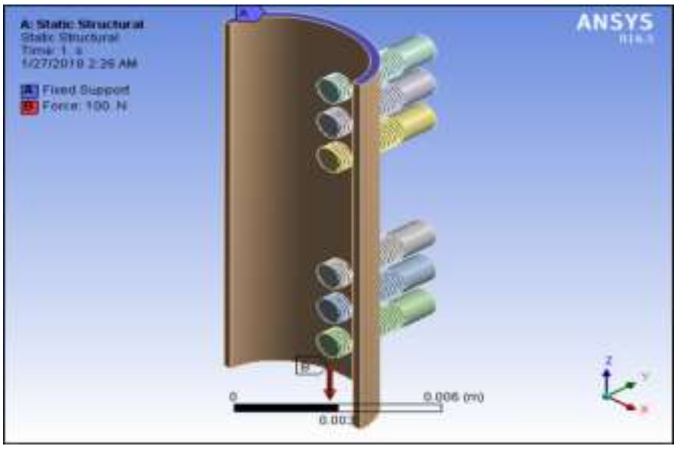


Figure. 8 .Load Applied on Hummensbone Section

3.3.1. Stress Analysis

As result of the stress engineering analysis ,it is clear that the stress generate in different value all over the bone, for example the maximum stress for PMMA+AL2O3 (41.52 Mpa) and (2.55Mpa) minimum value as shown in Fig. 9 and table 1. For PMMA+AL2O3+CF 1N the maximum value of stress was (43.44Mpa) and minimum (2.57Mpa) as shown in Fig. 10 While for PMMA+AL2O3+CF 2N inFig.11the value of stress change between (42.87 Mpa to 2.57 pa).But the material PMMA+ CF 1U the value of stress from43.22Mpa to 2.58 pa minimum value, Fig. 12 .Last material PMMA+AL2O3+CF 2U shows the maximum stress 43.0Mpa and the minimum 2.58 pa Fig. 13.

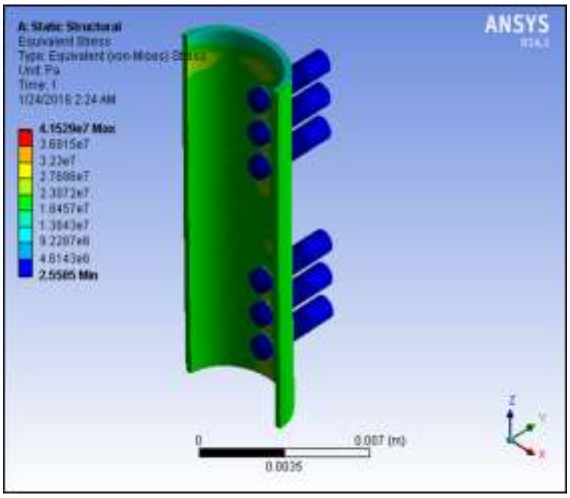


Figure 9 The stress Analysis for PMMA + AL2O3

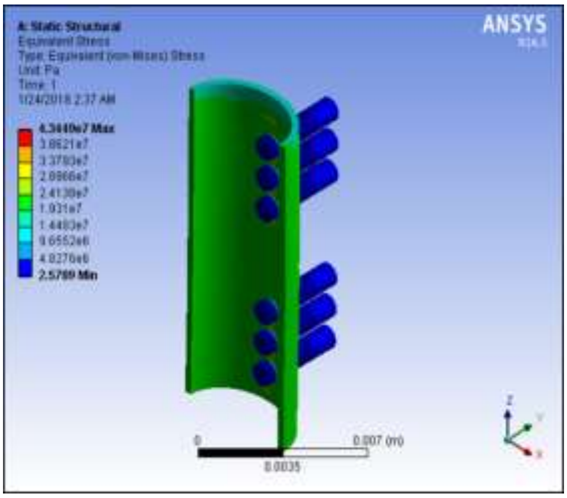


Figure 10 The stress analysis for PMMA +AL2O3 + CF 1N

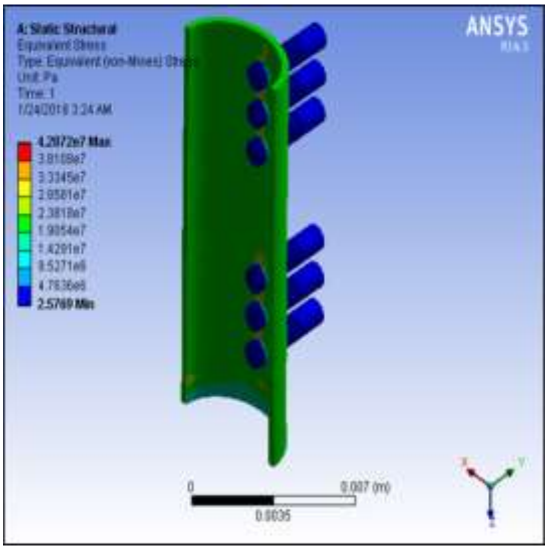


Figure.11. The Stress Analysis for PMMA+AL_2O_3+CF 2N

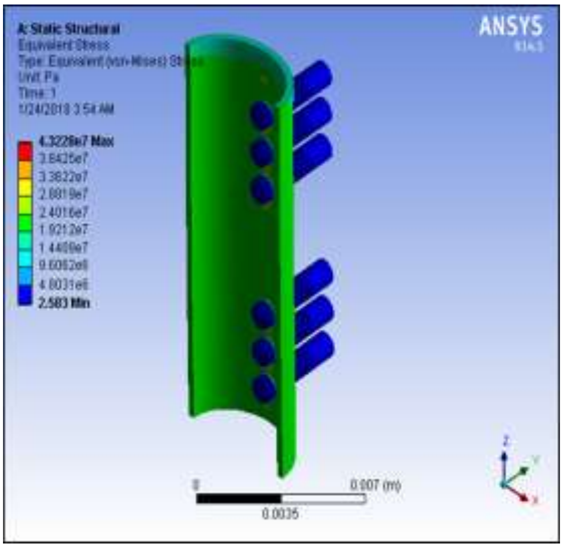


Figure.12. The Stress Analysis For PMMA+CF 1U

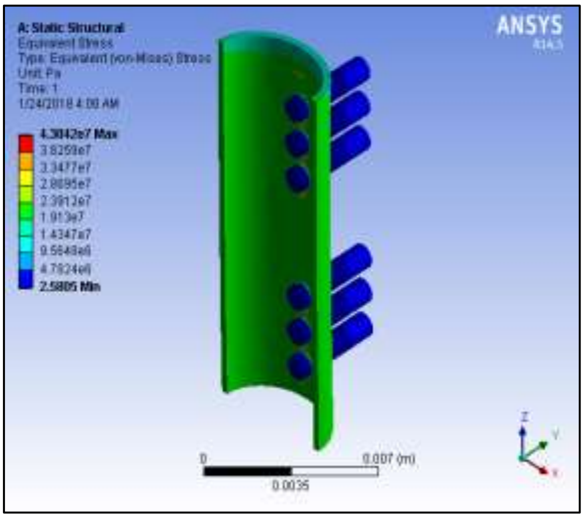


Figure.13. The Stress Analysis For PMMA+ AL_2O_3+CF 2U

3.3.2. Deformation Analysis

When force applied deformation should be occur for all materials .The value of deformation depend on the type of material. For the material PMMA+Al2O3 the max deformation 0.18 mm as shown in table 1and Fig.14.While the maximum deformation for composite PMMA+AL2O3+CF 1N 0.25mm Fig.15.But the material PMMA+AL2O3+CF 2N the deformation was 0.27mm, Fig.16.The composite PMMA+ CF 1U the maximum deformation 0.15 mm and0.18 mm for PMMA+AL2O3+CF 2U as shown inFig.s17&18 and table1 respectively .

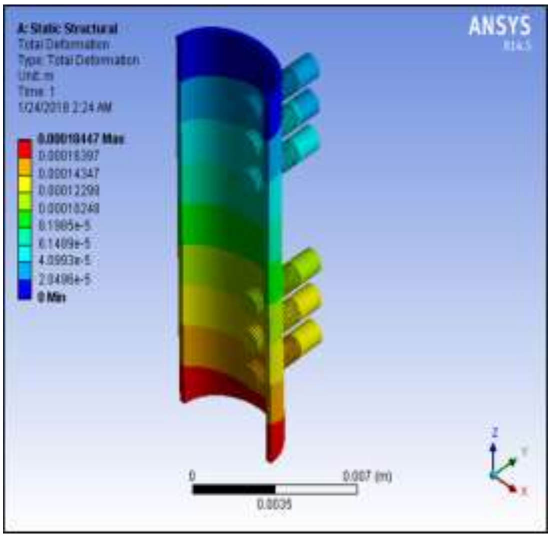


Figure.14.The Deformation for PMMA+AL2O3

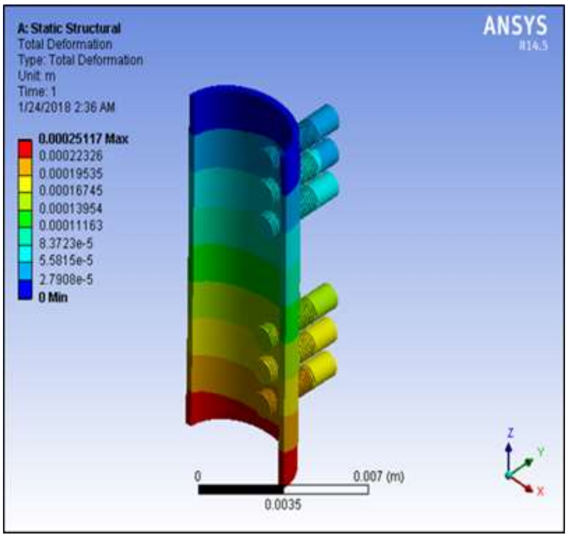


Figure.15.The Deformation for PMMA+AL2O3+CF 1N

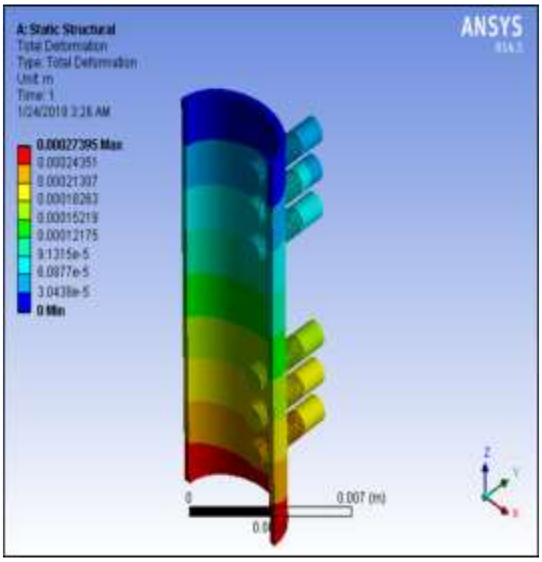


Figure.16.The Deformation For PMMA+AL2O3+CF 2N

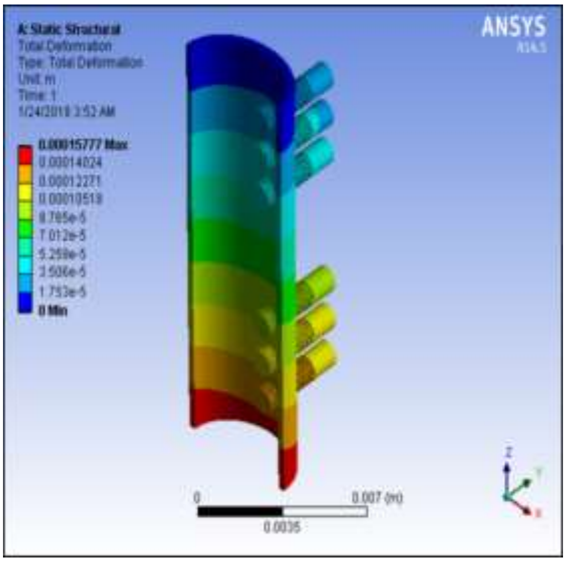


Figure.17.The Deformation For PMMA+ CF 1U

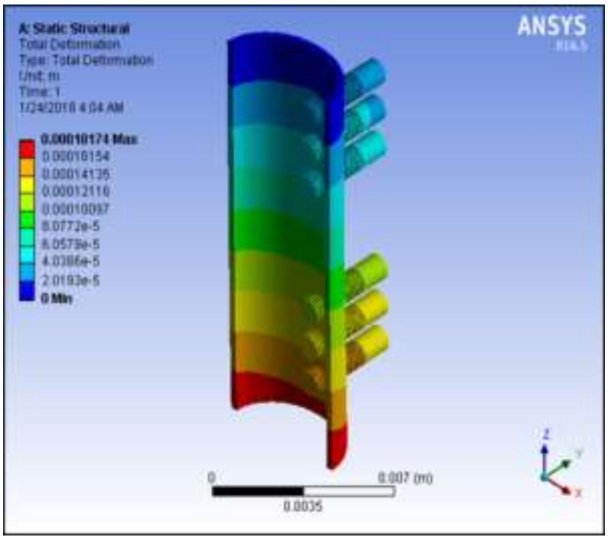


Figure.18.The Deformation For PMMA+AL2O3+CF 2U

4. CONCLUSIONS

- From the result illustrated in table (1)the best result a chive by using the material PMMA+ AL2O3 +CF 2U ,because the material able to resist fracture with high load .This is clear from the big different in the Yield stress value75.28 Mpa and density(1.3) g/cm3. That theoretical design supported mechanical properties with respect maximum deformation (0.18mm)&maximum stress(43Mpa).
- The polymer(PMMA) used as matrix reinforced by composite with two materials , Carbon-fibre(CF) made strong bridge to the PMMA and alumina (Al2O3) .
- The mechanical test of composite material has an improvement in the (PMMA+ AL2O3 +CF 1N & PMMA+ AL2O3 +CF 2N) respectively to the available material(PMMA+ AL2O3) at increasing the percentage CF with no uniform distribution . A high improvement in mechanical properties for several samples including1% Al2O3 ,97% PMMA & 2% when using CF with uniform distribution angle 45° composite (PMMA+ AL2O3 +CF 2U) .
- Microstructural surface((PMMA+ AL2O3 +CF 2U) investigations by using optical microscopy ,the Al2O3 particles is uniform distributed in polymer PMMA matrix and the line of CF is very clear in the form of network structure work as a bridge to increasing of bonding between PMMA matrix and Al2O3
- Energy dispersive spectroscopy (EDS) was used to investigate the chemical composition present of the elements in (PMMA+ AL2O3 +CF 2U) composite.

Samples

PMMA+ AL2O3 +CF 1N : polymer polymethyl methacrylate + alumina + Carbon fibers with non uniform distribution

PMMA+ AL2O3 +CF 1U: polymer polymethyl methacrylate + alumina + Carbon fibers with uniform distribution with 45°

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